Project Stage	General Topic	Specific Metric(s)	Analysis Already Agreed To By USAF?
Pre-Baseline			
	Monitoring Well Installations		
		Continuous logging	Y
		PID readings	Y
		LNAPL Dye Test; VOC and TPH if Dye Test is Positive	Y
		VOCs	Y
		TPH (DRO, GRO)	Y
Baseline Data			

Timing of Analyses	Frequency of Analyses	Location of Analyses
Before baseline geochemistry, field data, and microbial analyses performed	(Once - is an installation)	(Location of Installations)
	Once	CZ
	Once	UWBZ
	Once	LSZ
during well installation		Following Table 5.1
during well installation		Following Table 5.1
during well installation		Following Table 5.1
		Following Table 5.1
		Following Table 5.1

Purpose
These are additional wells to provide accurate monitoring of EBR
These MWs are needed to ensure that there are sufficient data to evaluate the effectiveness of EBR. The extraction wells can be used, but must be considered in separate groups and are not sufficient for this evaluation.
To determine if benzene is slower to degrade than other aromatics (or faster, or average)

To provide one singular, synoptic round of data prior to inception of EBR

Additional Comments

MWs are needed in suitable locations to monitor the effectiveness of EBR. Otherwise, data evaluation will be much less meaningful. Accurate delineation of concentrations in downgradient portions of the site should also be emphasized relative to off-site migration potential, sulfate utilization, etc.

To the degree possible, wells should also be located so that aquifer heterogeneities (low-permeability zones) can be monitored and accurate spatial averages for parameter values can be computed.

New MWs must have time to equilibrate after installation and development before baseline field data, geochemistry, and microbial analyses are performed.

7 treatment "ovals" proposed, but only 3 ovals have monitoring wells that are in reasonable locations. Monitoring wells should be installed in locations between the injection and extraction wells to evaluate sulfate distribution and EBR progress (5/ll/17 BCT slides, slide 25)
5 initial treatment "ovals" proposed; however, only one of the first 5 "ovals" where EBR is proposed for initial implementation has a monitoring well (ST012-UWBZ24). This well is not located in an optimal location for monitoring the effectiveness of treatment (i.e., it Is not located on the path between the injection and extraction wells). Since these ovals are proposed for the initial injections, at least one monitoring well should be installed in each oval treatment area so that the injections and EBR progress can be monitored. There are 5 additional treatment "ovals," but there are no monitoring wells in these ovals; monitoring wells should be installed (5/11/17 BCT slides, slide 26)
15 treatment "ovals" proposed, but only 2 have monitoring wells in suitable locations. 3 additional "ovals" have monitoring wells located beyond the extraction well. Depending on how the extraction wells are pumped, sulfate may never reach these monitoring wells. Monitoring wells should be installed in locations that are suitable to monitor injections and EBR progress. The wells located beyond the extraction wells should also be monitored to evaluate sulfate distribution (5/11/17 BCT slides, slide 27)
Taken from Table 5.1, RD-RAWP Addendum 2 (March 2016)
Taken from Table 5.1, RD-RAWP Addendum 2 (March 2016)
Taken from Table 5.1, RD-RAWP Addendum 2 (March 2016)
Taken from Table 5.1, RD-RAWP Addendum 2 (March 2016)
Taken from Table 5.1, RD-RAWP Addendum 2 (March 2016)

These data, collectively, will help establish baseline criteria against which project progress and goals can be compared and monitored.

Hydrogeologic Data

Groundwater gauge data (depth to water, depth to product, product thickness)	
Perform Slug Tests	

Mapping Contaminant Locations and Concentrations

Continue to locate and map LNAPL presence and depth	Y
Monitor benzene content and concentration in LNAPL, where LNAPL is found	Y
Continue to locate and map dissolved-phase benzene presence and concentration	Y
Continue to locate and map dissolved-phase VOC presence and concentration	
Calculate total LNAPL mass present at start of EBR	Y
Determine the content of COCs in the LNAPL at the start of EBR	
Locate and map sulfate concentrations	Y

Modeling

Provide a time estimate for sufficient COCs depletion in LNAPL, groundwater, and soil	

After SEE but before EBR injections or amendments	Once as baseline	New and existing MWs, located in the area to be impacted by injections/ amendments, and downgradient of this area
		All New Wells and Existing Wells that have not been tested
After SEE but before EBR injections or amendments	Once as baseline	New and existing MWs, located in the area to be impacted by injections/ amendments, and downgradient of this area
	monthly	Perimeter wells
		New and existing MWs with recoverable LNAPL
After SEE but before EBR injections or amendments	Once as baseline	Targeted treatment area and downgradient portions of the site

For use in modeling
Hydraulic Conductivity Measurement; for use in modeling
Refer notes in "modeling" section of this table.
Comparison of NAPL compositions before/during EBR to assess reductions in COC content
When compared to this baseline data, this information will help monitor for sulfate migration outside of the COC areas and facilitate comparison of EBR modeling results with field data

Data should be acquired for all three zones, including CZ

Synoptic measurements should be made to allow accurate development of hydraulic head maps and evaluation of groundwater to produce gw flow directions

Data should be acquired for all three zones, including CZ

See modeling comments by Bo Stewart, 5/17

Need to ensure good knowledge of locations where EBR treatments/amendments are being conducted, as well as downgradient

Need to develop a good baseline of initial NAPL content at locations where EBR treatments/amendments are being conducted, as well as downgradient

Report (graph) dissolved-phase trends over time, in addition to LNAPL trends for perimeter wells

ADEQ transmitted extensive comments on the most recent AF mass and composition estimates of remaining NAPL on May 16.

The existing characterization of NAPL composition is dated and displays a large deviation in a relatively small set of analyses. The most recent samples were collected from a NAPL holding tank. This NAPL was the combined recovery from the CZ, UWBZ and LSZ with unknown fractions from each. To allow a meaningful comparison of NAPL compositions before/during EBR to assess reductions in COC content, a large set of NAPL samples should be collected and analyzed separately from each zone and across each zone.

Please provide a detailed evaluation of important factors determining the efficiency and rate of COC biodegradation and depletion of COCs from the LNAPL source materials. In this evaluation, sensitivity analyses should be incorporated for evaluating the effect of assumptions on remedial efficacy and timeframe scenarios. This will aid in evaluating remedy effectiveness. Please use EPA-team modeled Time of Remediation estimates provided on May 30, 2017 as an example of the detail that should be provided. ST12 Joint agency EBR model cover letter.pdf; TOR Estimates_ST012_052217.pdf; BIONAPL_Box_Model_revised_04-27-2017_UWBZ.xls].

Provide details of EBR modeling to calculate time estimates for remediation	
Provide proof of concept supporting the sulfate reduction for EBR	
Provide details used to determine the optimal sulfate injection strategy.	

GW Geochemistry

Temperature	Y
pH	Y
ORP value	Y
Dissolved Oxygen	Y
Nitrate	Y
Phosphorus	
Ferrous Iron	
Total Iron	
Sulfate	Y
Hydrogen Sulfide	
Methane	
Alkalinity	
TPH (DRO, GRO)	Y
VOCs	Y
Arsenic	Y

Indigenous Microbial Population

Total size	
Major groups within population, and their proportion of total	

After SEE but before EBR injections or amendments	Once as baseline	New and existing MWs, located in the area to be impacted by injections/ amendments, and downgradient of this area
After SEE but before EBR injections or amendments	Once to establish baseline	Samplers should be placed so as to monitor the core of sulfate injections, its periphery, and downgradient. All three zones should be monitored. The same wells should be monitored pre-EBR, during EBR, and post-EBR.

These analyses will quantify the size, makeup, and health of the indigenous microbial community.

Please use EPA-generated models as an example of sufficient documentation, to allow for an independent evaluation of the results of the modeling.   Please see comments provided in: Techlaw memo dated March 24, emailed on April 11, 2017, and Time of Remediation estimates provided on May 30, 2017 (ST12 Joint agency EBR model cover letter.pdf; TOR Estimates_ST012_052217.pdf; BIONAPL_Box_Model_revised_04-27-2017_UWBZ.xls])

In particular, very little field data exists for the CZ and the UWBZ. The AF has not performed the EBR pilot test in the UWBZ that was agreed to in the ST012 Work Plan.

Reported on AF flowchart as Eh

AF decision flowchart only mentions "Iron" as an analyte, without differentiating which iron species will be monitored

AF decision flowchart only mentions "Iron" as an analyte, without differentiating which iron species will be monitored

All items other than the last metric, and using qPCR to determine the size of the sulfate-reducing population, are included as part of the already-proposed standard stable-isotope probe (SIP; Bio-Trap) study listed on the AF decision flowchart, but are not included in the metrics to be reported. All of these data are key to fully understanding the makeup, activities, and health of the indigenous microbial population.

These samplers cannot be used in LNAPL, but can be deployed underneath LNAPL.

Total size of sulfate-reducing bacteria population	Y
Total size of benzene-degrading bacteria population	
In-situ benzene degradation rate	
Amount of benzene converted to biomass during stable isotope study	Y
Amount of benzene converted to carbon dioxide during stable isotope study	Y
The overall health of the indigenous microbial population, as determined via PLFA analyses	
The dominant electron-accepting process for indigenous microbial population, and reason for the conclusion	

Assessments During EBR

Hydrogeologic Data

Groundwater gauge data (depth to water, depth to product, product thickness)	
Biofouling	Y

Mapping Contaminant Locations and Concentrations

Locate and map LNAPL presence and depth - monitoring wells	y
Locate and map dissolved-phase benzene presence and concentration	y
Locate and map dissolved-phase VOC presence and concentration	y
Calculate total LNAPL mass	
Determine the content of COCs in the LNAPL	

		New and existing MWs, located in the area to be impacted by injections/ amendments, and downgradient of this area
	quarterly	
During EBR		All new and existing MWs, located in the area to be impacted by injections/ amendments, and downgradient of this area
	Timing of sampling and analysis to follow schedule outlined in Table 4.1 of referenced document; mapping performed once per month	
	Quarterly	
	Quarterly	MWs with recoverable NAPL located in the area to be impacted by injections/ amendments

These assessments will be used to monitor the progress of EBR, and to determine if changes to the EBR strategy need to be made. These will also help monitor progress of EBR.

Comparison of NAPL compositions before/during EBR to assess reductions in COC content

qPCR performed in addition to the stable-isotope study.   AF decision flowchart references SRB gene, but Microbial Insights uses the APS gene to screen for sulfate reducers. Unclear as to what "SRB" gene is being referenced in flowchart.

Synoptic measurements should be made to allow accurate development of hydraulic head maps and evaluation of groundwater to produce gw flow directions

See AF Decision Tree

Need to ensure good knowledge of locations where EBR treatments/amendments are being conducted, as well as downgradient.   Timing schedule found in: Final Field Variance Memorandum #5 – Extraction and Treatment System Construction, Former Liquid Fuels Storage Area, Site ST012, Former Williams Air Force Base, Mesa, Arizona; 01 Dec 2016

Measurements of NAPL content, specifically benzene mole fraction, are a primary parameter for assessing EBR performance. See the "Figures" tab for example plots of benzene mole fraction. Refer to other comments in "modeling" sections of this table.

Modeling

Locate and map sulfate concentrations in the targeted treatment area as well as downgradient	Y
Provide a time estimate for sufficient COCs depletion in LNAPL, groundwater, and soil	
Provide details of EBR modeling to calculate time estimates for remediation	
Provide proof of concept supporting the sulfate reduction for EBR	
Provide details used to determine the optimal sulfate injection strategy.	

GW Geochemistry

Temperature	Y
pH	Y
ORP value	Y
Dissolved Oxygen	Y
Nitrate	Y
Phosphorus	
Ferrous Iron	
Total Iron	
Sulfate	Y

During EBR	At least annually	
During EBR	Monthly for the first quarter of EBR, followed by quarterly	New and existing MWs

Demonstrate achievement of remediation goals based on observed benzene concentration reductions in LNAPL and groundwater. Modeling and analyses of field data should also incorporate geochemical (e.g., sulfate) and microbial data (e.g., biomass) parameters that support hydrocarbon mineralization by biodegradation mechanisms (separate from dilution or sorption mechanisms). Modeling needs to evaluate rate-limited dissolution of LNAPL constituents so that the extent to which benzene and other hydrocarbon concentration reductions in groundwater are due to slow NAPL/aqueous-phase mass transfer (refer to example calculations in "Figures" tab). Sensitivity analyses should also be performed to rigorously document the variability of remediation timeframes as a function of EBR parameters.

To help monitor key microbial nutrient availability

Will help determine preferred TEA for indigenous microbes

Will help determine preferred TEA for indigenous microbes

To monitor if periodic sulfate injections or recirculation are necessary to sustain degradation rates

When compared to this baseline data, this information will help monitor sulfate migration outside of the COC areas

Please provide a detailed evaluation of important factors determining the efficiency and rate of COC biodegradation and depletion of COCs from the LNAPL source materials. In this evaluation, sensitivity analyses should be incorporated for evaluating the effect of assumptions on remedial efficacy and timeframe scenarios. This will aid in evaluating remedy effectiveness. Please use EPA-team modeled Time of Remediation estimates provided on May 30, 2017 as an example of the detail that should be provided. ST12 Joint agency EBR model cover letter.pdf; TOR Estimates_ST012_052217.pdf; BIONAPL_Box_Model_revised_04-27-2017_UWBZ.xls].

Please use EPA-generated models as an example of sufficient documentation, to allow for an independent evaluation of the results of the modeling.   Please see comments provided in: Techlaw memo dated March 24, emailed on April 11, 2017, and Time of Remediation estimates provided on May 30, 2017 (ST12 Joint agency EBR model cover letter.pdf; TOR Estimates_ST012_052217.pdf; BIONAPL_Box_Model_revised_04-27-2017_UWBZ.xls])

Ongoing updates as field data become available

These analyses will provide an indirect method of monitoring the indigenous microbial community.

Reported on AF flowchart as Eh

AF decision flowchart only mentions "Iron" as an analyte, without differentiating which iron species will be monitored

AF decision flowchart only mentions "Iron" as an analyte, without differentiating which iron species will be monitored

Hydrogen Sulfide	
Methane	
Alkalinity	
TPH (DRO, GRO)	Y
VOCs	Y
Arsenic	Y

TEA Injection Fluid

ICP Metals	Y
Details of injection material composition	
Sulfate	Y
Location of each injection/amendment	
Concentration of sulfate at each injection/ amendment location	
Anticipated zone of influence for each injection/ amendment	

Indigenous Microbial Population

Total size	
Major groups within population, and their proportion of total	
Total size of sulfate-reducing bacteria population	Y
Total size of benzene-degrading bacteria population	
In-situ benzene degradation rate	
Amount of benzene converted to biomass during stable isotope study	Y

During EBR, for every injection/ amendment event and location		
	Monthly, per Table 5.1 Need to check each batch	
During EBR, 6-9 months post-injection (per Decision Matrix)	At least once during EBR, 4-6 weeks after initial sulfate injection. May need to be repeated if geochem data suggests a problem.	Samplers should be placed so as to monitor the core of sulfate injections, its periphery, and downgradient. All three zones should be monitored. The same wells should be monitored pre-EBR, during EBR, and post-EBR.

To monitor if hydrogen sulfide concentrations inhibit degradation or will subsurface conditions mitigate their buildup?

To record makeup and concentration of injection fluid

Will the injected sulfate become well distributed with respect to NAPL accumulations?

These analyses will quantify the size, makeup, and health of the indigenous microbial community.

If there are indications that the microbial population is struggling during EBR, the analyses should be repeated to determine if alternate strategies are needed

May also help determine lag time for SRBs to acclimate to elevated sulfate concentrations and determine if highly concentrated injections of sulfate will be inhibitive to bacterial activity

Taken from Table 5.1, RD-RAWP Addendum 2 (March 2016);   This data will provide a record of exactly what was injected, where, and at what concentration. This, when compared with the response by the contaminants and other geochemical and biological data, will help determine if any changes need to be made to amendment variables such as frequency, concentration, etc.

Any metals over MCL would prevent ability to inject

This may be proprietary; however, an effort to obtain this information should be made

Need to check the TEA fluid before injection fluid before goes into ground to ensure that the concentration is as expected , was mixed and diluted correctly, etc.

All items other than the last metric, and using qPCR to determine the size of the sulfate-reducing population, are included as part of the already-proposed standard stable-isotope probe (SIP; Bio-Trap) study listed on the AF decision flowchart, but are not included in the metrics to be reported. All of these data are key to fully understanding the makeup, activities, and health of the indigenous microbial population.

These samplers cannot be used in LNAPL, but can be deployed underneath LNAPL.

Taken from Table 5.1, RD-RAWP Addendum 2 (March 2016).   AF decision flowchart references SRB gene, but Microbial Insights uses the APS gene to screen for sulfate reducers. Unclear as to what "SRB" gene is being referenced in flowchart.   qPCR performed in addition to the stable-isotope study.

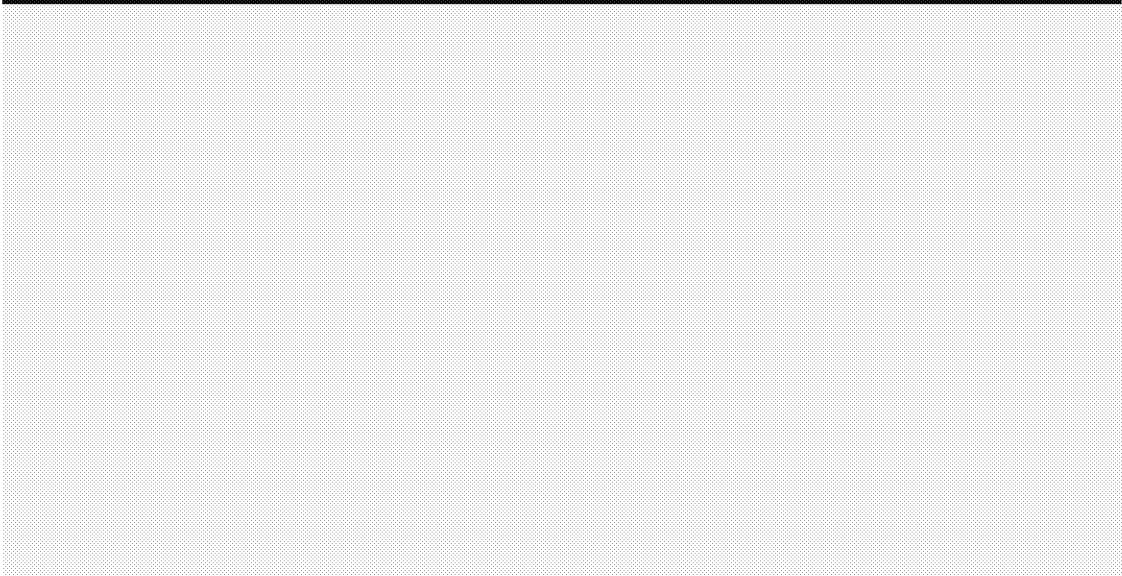|		
Amount of benzene converted to carbon dioxide during stable isotope study		Y
The overall health of the indigenous microbial population, as determined via PLFA analyses		
The dominant electron-accepting process for indigenous microbial population, and reason for the conclusion		

Post-EBR Data

Hydrogeologic Data

Groundwater gauge data (depth to water, depth to product, product thickness)		
Biofouling		Y

Mapping Contaminant Locations and Concentrations

Locate and map LNAPL presence and depth		
Locate and map dissolved-phase benzene presence and concentration, in excess of 5 ug/L		
Locate and map dissolved-phase VOC presence and concentration		
Calculate total LNAPL mass present		
Determine the content of COCs in the LNAPL		

Post-EBR		Each MW used for injections, amendments, or any analyses
	Minimum of semi-annual	
	once	
Post-EBR	Quarterly, then frequency amended per modeling and EPA guidance on MNA	Each MW used for injections, amendments, or any analyses
		MWs with recoverable NAPL located in the area to be impacted by injections/ amendments

This data will be compared against baseline data, and data taken during EBR, to determine the success of the project as well as to identify necessary future actions. This data will also become the baseline information used at the start of MNA

To ensure no biofouling after EBR

Comparison of NAPL compositions before/during/after EBR to assess reductions in COC content

EBR remedial goals include:

1) Depletion of COC concentrations (mole fractions) in LNAPL to the degree that the COC-depleted LNAPL cannot transfer COCs to groundwater above MCLs

2) Reduction of COC concentrations in site groundwater and soil to the degree that MNA could be expected (based on Regulatory Agency-approved modeling) to reduce COCs in groundwater below MCLs within the ROD remedial timeframe.

Specific numerical metrics, milestones, and timelines (i.e., specific concentrations of COCs in LNAPL and groundwater, along with associated geochemical and microbiological data, at specific times after initial implementation of EBR, and of MNA) will be developed based on Regulatory Agency - approved modeling efforts to guide remedial activities, evaluate success of the remedial approaches, and trigger contingency remedies if necessary.

Synoptic measurements should be made to allow accurate development of hydraulic head maps and evaluation of groundwater to produce gw flow directions

Pope, Daniel F., Steven D. Acree, Herbert Levine, Stephen Mangion, Jeffrey van Ee, Kelly Hurt, Barbara Wilson, Performance Monitoring of MNA Remedies for VOCs in Ground Water EPA/600/R-04/027, National Risk Management Research Laboratory Office Of Research And Development U.S. Environmental Protection Agency, Ada OK, 2004

Update based on additional field data

Measurements of NAPL content, specifically benzene mole fraction, are a primary parameter for assessing EBR performance. See the "Figures" tab for example plots of benzene mole fraction. Refer to other comments in "modeling" sections of this table.

Modeling

Locate and map sulfate concentrations in the targeted treatment area as well as downgradient	Y
Provide a time estimate for sufficient COCs depletion in LNAPL, groundwater, and soil by MNA	
Provide details of post-EBR modeling to calculate time estimates for remediation	

GW Geochemistry

Temperature	Y
pH	Y
ORP value	Y
Dissolved Oxygen	Y
Nitrate	Y
Phosphorus	
Ferrous Iron	
Total Iron	
Sulfate	Y
Hydrogen Sulfide	
Methane	
Alkalinity	
TPH (DRO, GRO)	Y
VOCs	Y
Arsenic	Y

Post-EBR	As needed	
Post-EBR	Quarterly, then frequency amended per modeling and EPA guidance on MNA	Each MW used for injections, amendments, or any analyses

Demonstrate achievement of remediation goals based on observed benzene concentration reductions in LNAPL and groundwater. Modeling and analyses of field data should also incorporate geochemical (e.g., sulfate) and microbial data (e.g., biomass) parameters that support hydrocarbon mineralization by biodegradation mechanisms (separate from dilution or sorption mechanisms). Modeling needs to evaluate rate-limited dissolution of LNAPL constituents so that the extent to which benzene and other hydrocarbon concentration reductions in groundwater are due to slow NAPL/aqueous-phase mass transfer (refer to example calculations in "Figures" tab). Sensitivity analyses should also be performed to rigorously document the variability of remediation timeframes as a function of EBR parameters.

When compared to this baseline data, this information will help monitor sulfate migration outside of the COC areas

Please provide a detailed evaluation of important factors determining the efficiency and rate of COC biodegradation and depletion of COCs from the LNAPL source materials. In this evaluation, sensitivity analyses should be incorporated for evaluating the effect of assumptions on remedial efficacy and timeframe scenarios. This will aid in evaluating remedy effectiveness. Please use EPA-team modeled Time of Remediation estimates provided on May 30, 2017 as an example of the detail that should be provided. ST12 Joint agency EBR model cover letter.pdf; TOR Estimates_ST012_052217.pdf; BIONAPL_Box_Model_revised_04-27-2017_UWBZ.xls].

Pope, Daniel F., Steven D. Acree, Herbert Levine, Stephen Mangion, Jeffrey van Ee, Kelly Hurt, Barbara Wilson, Performance Monitoring of MNA Remedies for VOCs in Ground Water EPA/600/R-04/027, National Risk Management Research Laboratory Office Of Research And Development U.S. Environmental Protection Agency, Ada OK, 2004

Reported on AF flowchart as Eh

AF decision flowchart only mentions "Iron" as an analyte, without differentiating which iron species will be monitored

AF decision flowchart only mentions "Iron" as an analyte, without differentiating which iron species will be monitored

Indigenous Microbial Population

Total size	
Major groups within population, and their proportion of total	
Total size of sulfate-reducing bacteria population	Y
Total size of benzene-degrading bacteria population	Y
In-situ benzene degradation rate	
Amount of benzene converted to biomass during stable isotope study	Y
Amount of benzene converted to carbon dioxide during stable isotope study	Y
The overall health of the indigenous microbial population, as determined via PLFA analyses	
The dominant electron-accepting process for indigenous microbial population, and reason for the conclusion	

Post-EBR	Once, within 3 months of the last injection/ amendment	Samplers should be placed so as to monitor the core of sulfate injections, its periphery, and downgradient. All three zones should be monitored. The same wells should be monitored pre-EBR, during EBR, and post-EBR.

These analyses will quantify the size, makeup, and health of the indigenous microbial community at the end of EBR, and will provide baseline data for MNA

All items other than the last metric, and using qPCR to determine the size of the sulfate-reducing population, are included as part of the already-proposed standard stable-isotope probe (SIP; Bio-Trap) study listed on the AF decision flowchart, but are not included in the metrics to be reported. All of these data are key to fully understanding the makeup, activities, and health of the indigenous microbial population.

These samplers cannot be used in LNAPL, but can be deployed underneath LNAPL. The use of the stable-isotope probes would be anticipated as a one-time event, unless groundwater data suggests a need to perform it again.

AF decision flowchart references SRB gene, but Microbial Insights uses the APS gene to screen for sulfate reducers. Unclear as to what "SRB" gene is being referenced in flowchart. qPCR performed in addition to the stable-isotope study.

Example calculations based on scenarios described in "Time of Remediation Estimates, Enhanced Bioremediation at ST01
Calculation input is provided in Tables 8-10 of the TOR memorandum

Table 8. Parameters for Monod Kinetics

Parameter		UWBZ	LSZ	Reference
V_{Soil}	yd^3	122,556	38,500	Table 2
Q	gpm	4.4	3.5	Table 2
k_{NAPL}	1/day	0.05	0.05	Mobile et al. (2016)
C^{O2} (backgrnd)	mg/L	7.0	7.0	Table M.4.3.2.1
C^{NO3-} (backgrnd)	mg/L	8.0	8.0	Table M.4.3.2.1
C^{SO4-} (backgrnd)	mg/L	200	290	Table M.4.3.2.1
γ_i^{SO4-}	g/g	4	4	Table M.4.3.5.3
$v_{Benzene,SO_4^{2-}}^{max}$	1/day	0.000875	0.0175	Table M.4.3.5.1/2
$v_{Toluene,SO_4^{2-}}^{max}$	1/day	0.001125	0.0225	Table M.4.3.5.1/2
$v_{Ethylbenzene,SO_4^{2-}}^{max}$	1/day	0.000875	0.0175	Table M.4.3.5.1/2
$v_{Xylenes,SO_4^{2-}}^{max}$	1/day	0.001125	0.0225	Table M.4.3.5.1/2
$v_{Naphthalene,SO_4^{2-}}^{max}$	1/day	0.000125	0.0025	Table M.4.3.5.1/2
$v_{TMB,SO_4^{2-}}^{max}$	1/day	0.000125	0.00125	Table M.4.3.5.1/2
$v_{Other\,Aromatics,SO_4^{2-}}^{max}$	1/day	0.000625	0.0125	Table M.4.3.5.1/2
$K_{SO_4^{2-}}^r$	mg/L	1	1	Table M.4.3.5.3
$K_i^{SO_4^{2-}}$	mg/L	5	5	Table M.4.3.5.3
Y	g/g	0.2	0.2	BEM (2007)
$M_{SRB,0}$ (initial)	mg/L	0.01	0.01	BEM (2007)
$\lambda_{SRB}^{d,bk}$	1/day	0.001 / 0.0	0.001 / 0.0	BEM (2007)

LSZ - Scenario 1

LSZ - Scenario 2

2" dated May 22, 2017
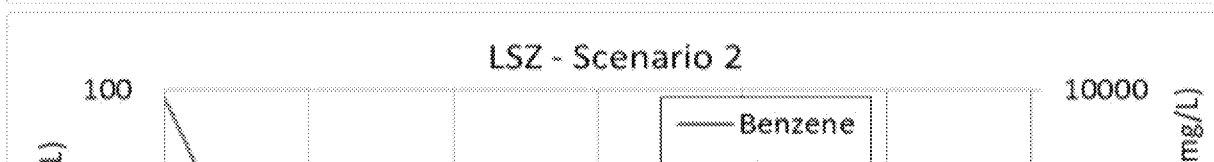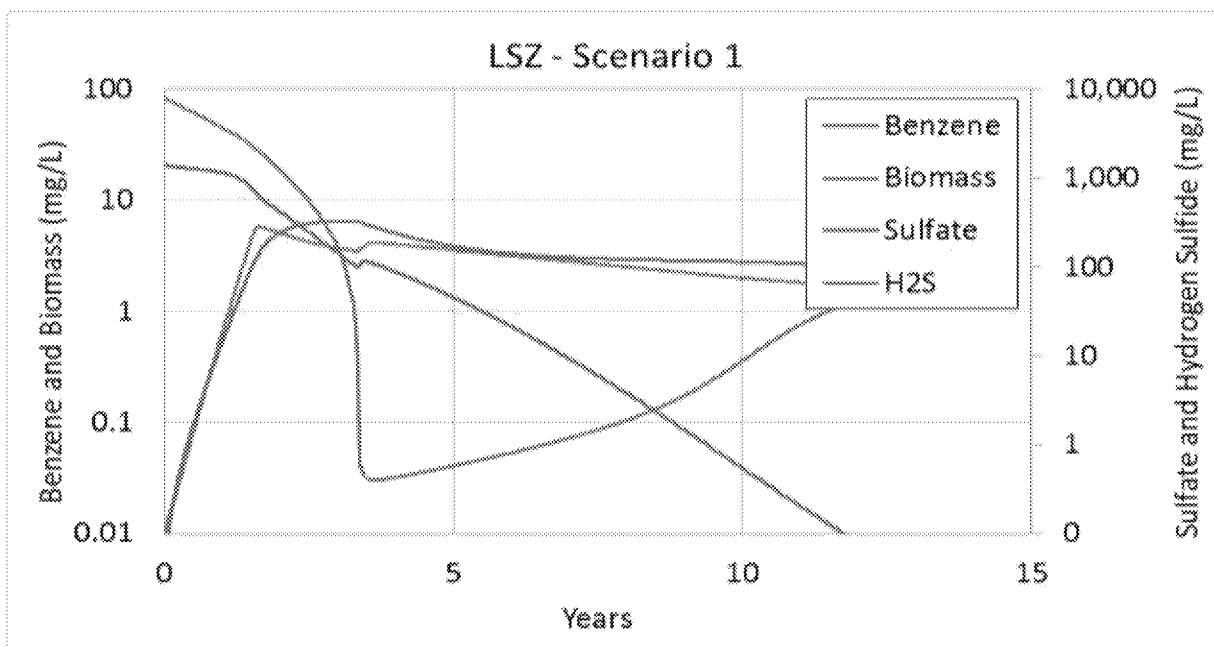
Table 9. Initial EBR-

Aquifer Zone		
UWBZ V = 122,556 cy	NAPL (gal)	
	Sulfate (kg) =	
	Sulfate (mg/L) =	
LSZ V = 38,500 cy	NAPL (gal)	
	Sulfate (kg) =	
	Sulfate (mg/L) =	

Table 10. TOR for NAPL Deple

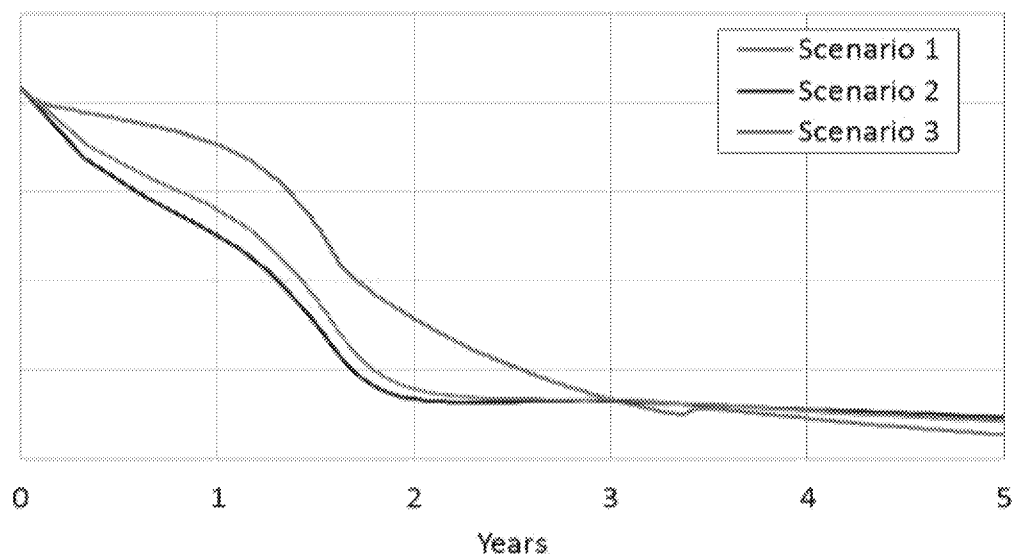| Aquifer Zone	Ambient Flow	Mass Transfer Coeff.	Calc Targe Vol Poros
	gpm	day^{-1}	ye
UWBZ	4.4	0.0042	1
UWBZ	4.4	0.05	
UWBZ	0.0*	0.05	1
LSZ	3.5	0.0042	5
LSZ	3.5	0.05	1
LSZ	0.0*	0.05	1

25

20

15

Benzene (mg/L)

10

5

0
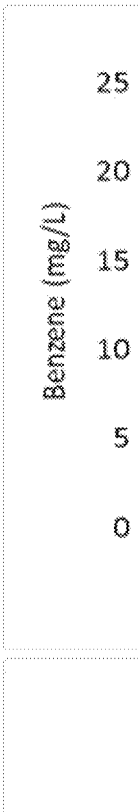
Targeted Sulfate Mass and Concentration

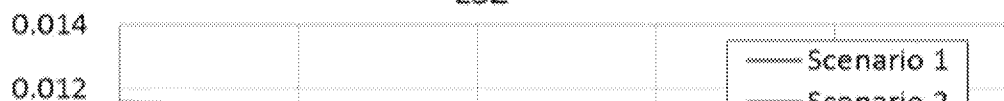| Calculated^ Target NAPL Volume Porosity=0.3 gal	Calculated^ Target NAPL Volume Porosity=0.4 gal	Literature* Target NAPL Volume Porosity=0.3 gal	Literature* Target NAPL Volume Porosity=0.4 gal
250,999	215,142	294,399	395,887
1,032,067	884,629	1,210,521	1,627,823
36,715	23,603	43,064	43,432
54,821	46,989	110,682	155,783
225,415	193,211	455,106	640,554
25,527	16,410	51,538	54,404

...tion with Sulfate Reduction and Monod Kinetics

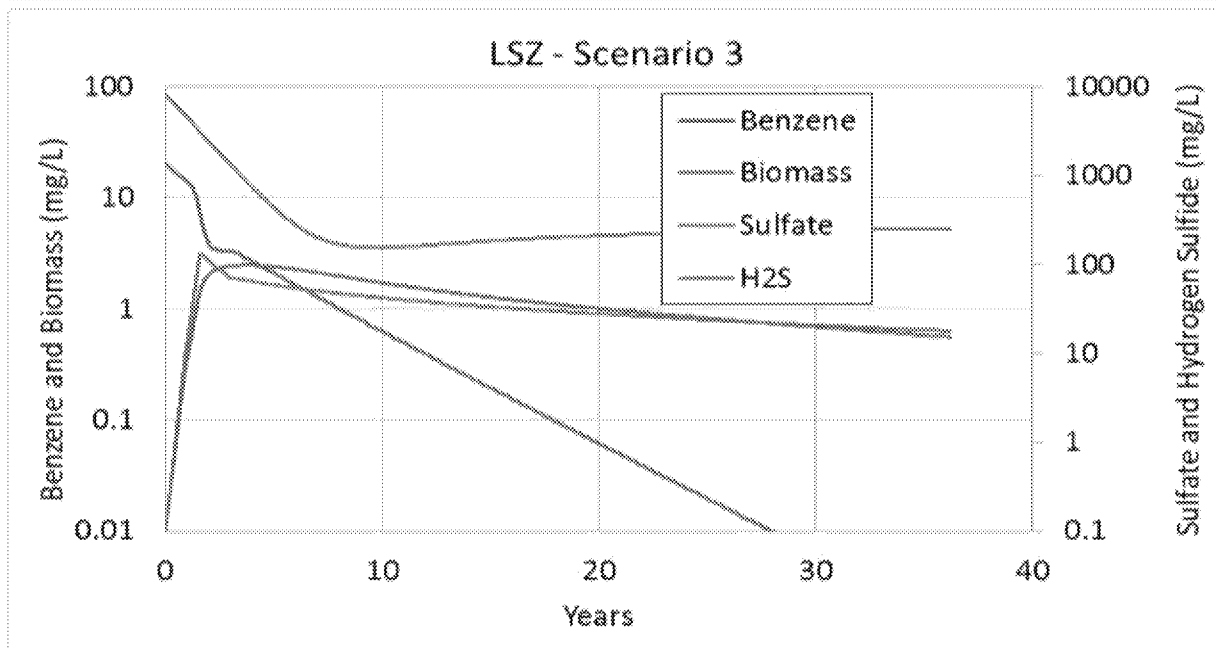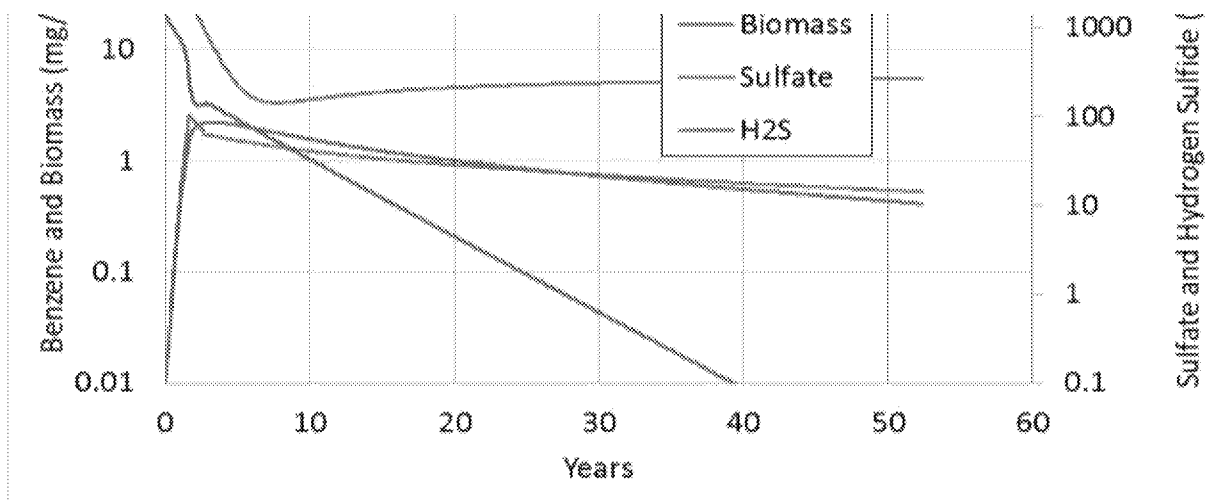| ...ulated t NAPL lume ...ity=0.3 ears	Calculated Target NAPL Volume Porosity=0.4 years	Literature Target NAPL Volume Porosity=0.3 years	Literature Target NAPL Volume Porosity=0.4 years	Notes
133	111	152	178	1
92	84	102	126	1
126	116	140	174	2
2.4	36.2	104	116	3
3.2	9.4	28.0	36.1	3
2.1	9.9	22.0	27.0	4

LSZ

Scenario 1
Scenario 2
Scenario 3

Years

LSZ

0.014
0.012

Scenario 1
Scenario 2

LSZ - Scenario 3

Benzene Mole Fraction

Sulfate Concentration (mg/L)

90
80
70
60
50
40
30
20
10

LSZ